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Anthropogenic Influence on Blackfin Sucker (Thoburnia atripinnis) Distribution, in the Upper Barren River System, Kentucky and Tennessee

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DEDICATION

This thesis is dedicated to my parents John and Jeanne Hurak for their support and assistance throughout this process. Without them this project would not have been possible.

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ABSTRACT

We evaluated the effects of land use and cover on endemic blackfin sucker (*Thoburnia atripinnis)* catch per unit effort and abundance within the Upper Barren River (UBR) system, a priority conservation area, in south-central Kentucky. Anthropogenic impacts have rendered *T. atripinnis* a "species of greatest conservation need" by the Kentucky Department of Fish and Wildlife Resources. This study focused on determining if land use surrounding blackfin sucker sampling sites and certain physicochemical parameters could be impacting their inhabitance at these sites. Data collection and ground truthing occurred between September 2015 and June 2016. ArcGIS was used to extract land use proportions within 100m and 390m buffers around 41 sites and ERDAS imagine was used to create a supervised and unsupervised classification of the study area. Based on the error matrices land use/cover was classified with higher accuracy values for supervised classification over unsupervised classification. Within the study area, Barren River and Long Creek watersheds were found to be made up of primarily forest while Beaver Creek, Skaggs Creek, and Peter Creek watersheds were mainly hay pasture. Principal component analysis (PCA) was utilized using 11 variables to investigate the impact of land use/cover and physicochemical parameters on blackfin sucker catch per unit effort (CPUE). No significant correlations between principal components and blackfin sucker CPUE occurred. Stepwise regression models revealed that temperature was the best explanatory variable for blackfin sucker CPUE. Although no statistically significant results were found, this study showed how ArcGIS and remote sensing techniques can

be applied to a pre-existing biological dataset. However, with these results, further conclusions can be drawn about the blackfin sucker and their ideal habitat.

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INTRODUCTION

Landscape development is a rising global issue for the ecological integrity of stream ecosystems (Allan 2004). Rivers are influenced by the landscapes they flow through and in a sense the “valley rules the stream” (Hynes 1975). Anthropogenic on-shore activities, such as agriculture, deforestation, and urbanization are increasing at a steady rate worldwide (McCulloch et al. 2003; Syvitski et al. 2005; Oost et al. 2007; De’ath and Fabricius 2008), and are increasingly recognized to impact water quality, habitat, and biota in many ways (Allan et al. 1997; Strayer et al. 2003; Townsend et al. 2003). On-shore impacts e.g. sedimentation, nutrient enrichment, contaminant pollution, hydrologic alterations, riparian clearing, canopy opening, and loss of woody debris can lead to extreme changes to allochthonous inputs and alter normal stream function (Allan 2004). Changes in stream function and quality can lead to the imperilment of sensitive fauna or cause them to become locally extinct in extreme cases. As a result of anthropogenic activities, emerging problems raise concerns for freshwater fishes and their impacted habitats across the United States. Sutherland et al. (2002) states that North America has the highest diversity of temperate freshwater fishes in the world, with many species residing in the Southeastern United States (Walsh et al. 1995; Warren et al. 2000). Many imperiled fish species in this area are reliant on cobble-gravel substrate which can be destroyed as a result of anthropogenic landscape modifications (Sutherland et al. 2002). Increased sedimentation and turbidity are direct results of agriculture, forestry, urban development, mining and road construction (Waters 1995). These impacts can impede primary and secondary production within stream ecosystems, further influencing fish abundance, biodiversity, and assemblages (Dudgeon 2000).

Historically in Appalachia, the intrusion of humans into riparian zones of rivers resulted in a mosaic of forested and deforested habitats, and stream fishes are now subject to those alterations to stream habitat (Jones et al. 1999; Bolstad et al. 1998). The conversion of stream watersheds from forest to agriculture over time has led to the destabilization of stream banks, sedimentation increases from erosion, increases in non-point pollutants due to fertilizers and biocides, and alterations of light and thermal regimes as well as stream hydrology (Jones et al. 1999; Allan 2004). These physical changes to stream environments have been linked to negative impacts on water quality, habitat, and biological assemblages (Richards et al. 1996; Roth et al. 1996; Sponseller et al. 2001; Wang et al. 1997). An increase in sediment input and turbidity alone can lead to loss of condition in fish species incapable of feeding across the water column and can further decrease useable habitat spaces of “refugia” for species in an impacted aquatic system (Sullivan and Watzin 2010).

In addition to the impacts of agriculture on a stream, many freshwater systems are further altered by artificial impoundments. River damming is an extreme anthropogenic impact affecting freshwater environments that leads to habitat loss, changes in fish reproductive habitats, and barriers to migration routes (Baxter 1977; Park et al. 2003). Long-term effects of damming can result in species isolation, which can lead to a decrease in biodiversity, fish functionality, and species richness overall (Park et al. 2003; White et al. 2012). Managing offshore inputs into streams and preserving the connectivity of different habitats within a river network are important to address when developing management and conservation plans for fish populations (Sullivan and Watzin 2010).

Quantifying land uses and land covers within catchment areas of streams is a valuable tool (Meyer and Turner 1994) for identifying impacted areas in need of conservation efforts (Compton and Taylor 2012). Since Hynes (1975) discussed the importance of looking at streams and valleys as a whole, the interactions of both the stream and its catchment area are increasingly acknowledged (Johnson and Gage 1997). In the past, ecological stream studies have focused on a stream reach scale; however, in order to grasp the magnitude of some disturbances, a much broader spatial scale must be utilized (Johnson and Gage 1997). Geographical Information Systems (GIS), image processing, and remote sensing methods using satellite imagery can be applied to complex questions in ecology (Johnson and Gage 1997). GIS has a wide range of capabilities and is a useful tool for ecologists and conservation managers. Additionally, it makes catchment area scale studies a possibility (Johnson and Gage 1997).

The landscape changes affecting the Upper Barren River (UBR) make it a prime example of a catchment where GIS technologies may be useful for examining land use/cover changes. Agricultural land use impacts are present within the UBR system in south-central Kentucky and action has not been taken to determine the impacts on the blackfin sucker (*Thoburnia atripinnis)*, an endemic fish species found in the Upper

Barren River system. In addition to agricultural impacts in the UBR, the Army Corps of Engineers impounded the system in 1964 to create a 10,100-acre reservoir (Kleber 1992). Dam construction on the Barren River system may introduce difficulties for blackfin suckers with regards to the change and loss of useable habitat and abundance within the UBR watersheds. The Barren River damming in conjunction with the increased agricultural land use within the catchment area can lead to major habitat alterations for blackfin suckers. GIS was used to determine how damming and agriculture in the UBR may affect blackfin sucker abundance and distribution.

Life History and Habitat

The blackfin sucker is one of three species that comprise the genus *Thoburnia* (Bailey 1959) and is the focal species of this study (Figure 1)[1]. The blackfin sucker is a relict species only occurring in the Upper Barren River (UBR), within the Green River system, located in south-central Kentucky and north-central Tennessee (Bailey 1959; Etnier and Starnes, 1993). Bailey (1959) described this endemic species and differentiated it from its western relatives: *Thoburnia hamiltoni*, located in the Roanoke River system in Virginia (Raney and Lachner 1946) and *T. rhothoeca* (Thoburn), which is characteristic to the James River drainage, Virginia, and the Shenandoah headwaters and New Rivers within the Potomac and Kanawha River systems in Virginia and West Virginia (Bailey 1959). Bailey (1959) considered the blackfin sucker as a "highly

[1] Tables are present in Appendix A. Figures are located in Appendix B.

distinctive fish," less adaptive to torrent mountainous environments than other *Thoburnia* species.

Thoburnia is thought to be related to *Moxostoma,* and *T. atripinnis* narrows the gap between the genera (Bailey 1959). *Thoburnia atripinnis* is in the subfamily Catostominae and Tribe *Thoburniini* (Hubbs 1930). This tribe consists of two genera, *Thoburnia* and *Hypentelium* (hogsuckers), both located in eastern North America (Harris et al. 2002). The classification of *Thoburniini,* as its own tribe, is due to certain structural features; an obsolete air bladder seen in adults, an obliterated fontanelle, and subplicated lips (Hubbs 1930). Bailey (1959) agreed with the pairing of *Thoburnia* and *Hypentelium* due to the reduction in the swimbladder and fontanelle closure, which are adaptive features to life in swift waters.

The blackfin sucker has a total maximum length of 155mm (Etnier and Starnes 1993). The back is marked with two prominent black blotches (saddles); one at the dorsal fin base and another above the anal base fin, which are inclined downward and forward (Bailey 1959). The blackfin sucker has 46-50 lateral line scales, 16 caudal peduncle scale rows, 16-20 predorsal scale rows, 10 dorsal fin rays, and nine (8-9) pelvic fin rays with 16-20 gill rakers in specimens exceeding 80mm in length (Etnier and Starnes 1993). The body has two dark horizontal lines below the lateral line and six or seven additional dark lines in the dorsolateral area (Etnier and Starnes 1993). The dorsal fin has a distinctive black blotch on the distal anterior 5 or 6 rays (Etnier and Starnes 1993). Bailey (1959) considered the dorsal fin pigment, body, and the peritoneum the best ways to identify the blackfin sucker. Breeding males have granular tubercles over the head and nuptial tubercles (pearl organs) on the anal and caudal fins (Bailey 1959). The blackfin sucker is known to have a smaller mouth and lips (Raney and Lachner 1946) and silvery melanophores (Bailey 1959) when compared to other related species. At 2 years, blackfin suckers are considered "invariably mature" and at 3 years an individual is considered mature (Bailey 1959).

Blackfin suckers inhabit streams surrounded by low, rolling hills with soils of low to medium fertility, frequent bedrock outcrops, and land not subject to excessive farming and agriculture (Timmons et al. 1983). Findings by Stringfield (2013) were consistent with those of Timmons et al. (1983) however, blackfin suckers were found in Kentucky sites predominantly surrounded by hay/pasture land and row crops, in some cases. Stringfield (2013) also collected blackfin suckers all across the UBR at sites characterized by a wide range of physicochemical attributes and surrounding land uses in Kentucky and Tennessee. Catch per unit effort (CPUE) was higher at Tennessee sites, while other sites in Kentucky had relatively high CPUE despite increased agricultural land use in the state of Kentucky. So although blackfin suckers were reported to prefer the habitat described by Timmons et al. (1983) their range is widespread across the UBR. The majority of individuals have been found in clear streams with flow rates between 0.1 to 1.4 m/s; and with an alternating pattern of pools and riffles consisting of gravel, rubble, limestone, shale, and siltstone (Bailey 1959; Timmons et al. 1983). Aggregations of adult blackfin suckers have been observed along shorelines, in pools with overhanging brush and swimming into bedrock crevices, and under large rocks (Timmons et al. 1983). Stringfield (2013) collected blackfin suckers under bedrock ledges, slab and boulders which is consistent with the findings of Timmons et al. (1983). On some occasions blackfin suckers were captured under bridge pillar supports, shallow riffles, and detritus pools, yet crevices remain an important niche that blackfin suckers inhabit (Stringfield 2013). Pools and riffles are important breeding habitats for the blackfin sucker (Bailey 1959). During the spawning season, males remain behind large riffle rocks; while females inhabit pools and the underside of flat rocks at the riffle's edge. Water depth contributes to ideal microhabitat for blackfin suckers and they are more likely to be found in deeper areas in pools within a stream (Stringfield 2013).

Concerns and Project Goals

Due to blackfin sucker isolation and endemism, personnel with the United States Fish and Wildlife Service (USFWS) are concerned with its conservation (Stringfield 2013). The blackfin sucker is considered a "species of greatest conservation need" by the Kentucky Department of Fish and Wildlife Resources (KDFWR) and is also listed in Tennessee as a species of special concern (KDFWR 2005). Because the blackfin sucker is endemic to the UBR, this species will require specific conservation planning in order to ensure the preservation of its required habitat. Threats to the species in the UBR include siltation, stream channelization, and stream eutrophication caused by an increase in nutrients and agricultural runoff (Warren et al. 1997). Sedimentation alone can destroy rock outcrops, described by Timmons et al. (1983), as a common useable habitat for blackfin suckers. The way land is utilized in areas within the immediate or distant vicinity of a stream can disrupt stream functions and natural cycles and land use/cover could be impacting the UBR and blackfin suckers in a negative way.

The goal of this study was to determine if blackfin sucker abundance and distribution were correlated with watershed (i.e., catchment area, land use) and/or reach-level habitat attributes and if this differed among the 5 watersheds that make up the UBR. Thus, the objectives of this study were to: (1) describe habitat at varying spatial scales among the 5 individual watersheds; (2) and determine any association with blackfin sucker abundance and distribution across the watersheds. Observing the landscape at varying spatial scales helped determine if reach or watershed scale parameters are having effects on blackfin sucker CPUE and distribution within the UBR. These methods helped to differentiate the dominant land uses and coverages in the five main UBR watersheds and identify possible problem habitat for the blackfin sucker. Blackfin sucker CPUE was expected to be lower in the watersheds and individual sites surrounded by higher proportions of agricultural land use.

CHAPTER 2

STUDY AREA

The Upper Barren River (UBR) system is located within the Green River network in the Interior Low Plateau of Kentucky; the UBR is an area of conservation priority due to its ichthyological importance (KDFWR 2005). The UBR drainage spans four counties in south-central Kentucky (Allen, Barren, Metcalfe, and Monroe), and two in north-central Tennessee (Clay and Macon). The land uses within these counties are mainly agriculture and hay pasture. There are five main watersheds that contribute to the Barren River reservoir: Barren River, Skaggs Creek, Beaver Creek, Peter Creek, and Long Creek. The smaller tributaries contributing to the system from the headwaters in Tennessee include: Big Trace Creek, Hurricane Creek, Little Salt Lick Creek, Long Creek, Salt Lick Creek and Trace Creek. All watersheds mentioned above are located above the Barren River reservoir. Stringfield (2013) sampled 41 sites in Kentucky and Tennessee and confirmed at least 28 blackfin sucker sites in the UBR and classified blackfin sucker habitat at a reach and microhabitat scale (Table 1 and Figure 2). Field work was performed from May to July 2016 throughout the study area.

Chapter 3

METHODS

Remote Sensing Applications

ERDAS Imagine software and remote sensing image classification techniques were used to analyze remote sensing and non-remote sensing (ancillary) data. This was utilized in order to develop an unsupervised and supervised classification of study area satellite imagery. Five main land use and cover classes, through use of an unsupervised classification, were determined: water, developed, hay pasture, cultivated crops and forest. In order to develop a supervised classification, ground truthing and high resolution National Agriculture Imagery Program (NAIP) imagery verifications were performed using 250 equalized random GPS points generated through ERDAS (Figure 3). Fifty random points per class (250) were used for the supervised classification. Twenty-five points, per class, were verified using ground truthing methods and a DeLorme Earthmate PN-60 Hiking GPS Navigator, while the other 25 points were verified using NAIP imagery from 2014 (US Department of Agriculture 2016) (Figure 4). However, all 50 water gps points were confirmed using the same NAIP imagery. Ground truthing was performed from May through July of 2016. Once all the data were collected an accuracy assessment was conducted for both classifications to find producer's accuracy, user's accuracy, overall accuracy and kappa values. The producer's accuracy being how well an area can be classified. User's accuracy reports on the probability of the pixel class representing the class that is on the ground. Overall accuracy is a value attained by dividing the number of correct pixels by the total number of pixels within the error matrix. While the kappa value is a measurement of agreement between the classification map and reference data

Landsat 8 satellite imagery was utilized for remote sensing purposes in order to classify land use/cover in the UBR. Landsat 8 (ESRI 1996), launched in February 2013, provides geospatial imagery which allowed for improved resolution without altering spectral data. Having 11 spectral bands made Landsat 8 imagery ideal for the goals of this project, providing a 30 x 30 meter spatial resolution and 16 day temporal resolution.

Land Use and Land Cover

ArcGIS (ESRI 1996) software was used to analyze land use/cover raster data. General proportions of land use and cover for the 5 distinct watersheds in the Upper Barren River were determined using the extract by mask tool, reclassified 2011 National Land Cover Database (NLCD) raster data, and huc (hydrologic unit code) 11 and 14 data (US Department of Agriculture 2016) in order to characterize the watersheds on a broad scale. To examine the watersheds on a finer scale, a 100 meter and a 390 meter radius buffer were used to classify coverage around the 41 sites sampled by Stringfield (2013). A 100 meter circular buffer was chosen based on methods described by Sutherland et al. (2002). The 390 meter buffers were used to look at a larger area surrounding each site without overlap. Land cover and use proportions were calculated from each site's buffer using the extract by mask tool and raster pixel counts.

Habitat and Blackfin Sucker Spatial Associations

Combinations of reach and microhabitat-scale parameters were available from Stringfield (2013) characterizing the 41 blackfin sucker study sites throughout the UBR (Table 2). Parameters used include catch-per-unit effort (CPUE) and abundance of blackfin suckers, physicochemical parameters: pH, temperature (°C), dissolved oxygen (mg/l), and conductivity (µmhos).

Statistical Analysis

Because differences in abundance and CPUE effort are likely caused by multiple abiotic and biotic factors, multivariate techniques were used to investigate the effects of 11 variables. Land use and cover proportions (100m and 390m) for forest, developed, hay pasture, agriculture, and other, extracted through ArcGIS, were used in this analysis. Site elevation was also extracted using ArcGIS. Land cover and use proportions were arcsine- square- root transformed. Other variables used included dissolved oxygen, temperature, pH, conductivity, and average reach depth collected by Stringfield (2013). Dissolved oxygen, average reach depth, elevation, and temperature were $\log_{10}$ transformed to meet the assumptions of normal distribution of errors and constant variance. Conductivity was of a linear form and pH was measured in logarithmic units; therefore, these independent variables were not log transformed.

Using PC-ORD (McCune and Mefford 2016), a principal component analysis (PCA) was utilized to detect patterns between the physicochemical and land cover/use datasets in order to characterize sample sites based on correlated watershed, reach and microhabitat parameters (Compton and Taylor 2012). Secondly, Pearson correlations (Pitois et al. 2015) were used in Excel to detect relationships between principal component scores (100m and 390m) and catch per unit effort. Lastly, a step-wise regression (Kabe 1963) was performed in SAS version 9.3 (http://www.sas.com/en_us/software/sas9.html) to determine if a relationship existed between blackfin sucker CPUE, physicochemical data, and land cover/use proportions at 2 buffer sizes (100m and 390m). Statistical significance was evaluated at α=0.05. Stepwise regression statistical significance was evaluated at α=0.15.

Chapter 4

RESULTS

The study area satellite imagery is depicted in unsupervised and supervised computer classifications (Figure 5). Colors for the various land use types are: green = forest, yellow = hay pasture, red = agriculture, purple = developed, and blue = water. The supervised classification error matrix compared the classified data with the ground truthing data for the 250 observations within the study area (Table3). The overall accuracy for the supervised classification was 84.80% with an overall kappa value of 0.81. The producer's accuracy for the individual categories ranged from 70.7% for agriculture to 94% for water, whereas the user's accuracy ranged from 64% for developed to 94% for water and forest. Thomlinson et al. (1999) explain that a target for classifications should be an overall accuracy of 85% with no classes less than 70%. For overall kappa a value of >0.80 serves as the criteria for a good classification. However, Olofsson et al. (2014) states that reporting kappa, although it still has widespread use, has become discouraged when reporting accuracy assessment results due to redundancy with overall accuracy.

An error matrix for an accuracy assessment was generated for the unsupervised classification (Table 4). The producer's accuracy for individual categories ranged from 5.26% for Agriculture to 96.23% for forest. The user's accuracy for the individual categories ranged from 15.79% for agricultural areas to 88.89% for water. The low user's and producer's accuracy was due to confusion with developed, hay pasture, and cultivated crops during the classification and difficulty in separating these classes spectrally. The kappa estimated value for the unsupervised classification was .4399 with an overall accuracy of 55.20%.

Land use and land cover proportions were extracted at all 41 Stringfield sampling sites using a 100m buffer and a 390m buffer (Table 5 and 6). Land use and land cover proportions were also extracted from the 5 individual watershed areas as a whole (Table 7). Three of the watersheds were mainly hay pasture (Beaver Creek 55.8%, Skaggs Creek 48.6%, and Peter Creek 50.2%, respectively). Barren River and long Creek were primarily forest (48.5% and 54%, respectively).

Principal components utilizing land uses at 100 meters indicated that the first three axes accounted for 57% of the variance among sites (Table 8). PC1 described 28.12% of the variance, with the greatest loading being placed on hay pasture (-0.50) followed by developed (-0.42) and forest (0.41). PC2 (14.74% of variance) was driven by agriculture (0.55), dissolved oxygen (0.53), and water temperature (-0.53). PC3 (13.77% of variance) was largely driven by average reach depth (0.60) followed by dissolved oxygen (-0.42) respectively.

Principal components utilizing land uses at 390 meters indicated that the first three axes accounted for 59% of the variance among sites (Table 9). PC1 contributed 32.15% of the variance, with the greatest loading being placed on hay pasture (-0.46) followed by forest (0.45) and other (0.40). PC2 (14.05% of variance) was driven by dissolved oxygen (0.69) and temperature (-0.53). PC3 (12.73% of variance) was largely driven by average reach depth (0.58) and agriculture (0.53), respectively. There were no significant correlations between principal component scores and blackfin sucker CPUE

(Table 10). The closest to being significant ($p<0.05$) was PC2 at 100m ($R=-0.27$, $p=0.09$). However, PC2 at 100m only explained 14.74% of variance amongst sites.

The stepwise regression models revealed that temperature was the best explanatory variable for blackfin sucker CPUE. Temperature ($p=0.086$ at 100m and 390m) was significantly ($p<0.15$) associated with CPUE when looking at both 100 m and 390 m datasets. All other variables, including land cover and use proportions were deemed insignificant ($p>0.15$).

Chapter 5

DISCUSSION

Through use of ArcGIS, data conclusions were able to be drawn about the five distinct watersheds that make up the UBR. Land use and cover extractions showed that Barren River and Long Creek had the highest percentage of forest while the remaining three watersheds, Beaver, Skaggs and Peter, were mainly hay pasture. The Barren River and Long Creek watersheds make up the major forested headwaters in the UBR system. This agrees with the conclusions of Stringfield (2013) in the sense that these two watersheds are located in Clay and Macon county, which are in headwaters located in Tennessee. Although Timmons et al. (1983) described historic blackfin sucker sites as undisturbed and not extensively farmed areas, Stringfield (2013) collected blackfin suckers at sites with varied landscapes. We found land use/cover proportions extracted from Tennessee and Kentucky sites did not show an impact on catch per unit effort. Although the majority of Stringfield sites were located in the Barren River watershed, blackfin suckers were found at sites surrounded by a variety of different land use/cover. So our findings along with the findings of Stringfield contradict blackfin sucker preferred habitat reported by Timmons et al. (1983). There seems to be no negative impacts among physicochemical data and extracted land cover and use proportions and blackfin sucker CPUE as was expected. These results may indicate that blackfin suckers are more adaptive to their changing environment or that significant impacts may have more of a long term effect that are not detectable at present. Land use changes occur slowly over time and future monitoring of their affects can be beneficial to species like the blackfin sucker and of interest habitat like the UBR.

Pitois et al. (2015) was able, through use of principal component analysis (PCA) combined with Hierarchical Cluster Analysis (HCA), to show ecosystem transition over time and weak positive correlations between principal components and mackerel larvae yearly abundance. With principal components and correlations, we were unable to see any correlation among habitat variables, land use/cover proportions, or blackfin sucker abundance. It may be beneficial in the future to continue to monitor these blackfin sucker sites in order to determine changing spatial dynamics of blackfin sucker abundance over time. Despite the lack of statistically significant findings, we were successfully able to apply GIS and remote sensing techniques to an already existing dataset which is a relatively new concept in the field of ecology. Land use/cover around blackfin sucker sites were able to be defined using GIS and the entire area of the Upper Barren River system was able to be classified at an overall accuracy of 84.8% using remote sensing and Erdas Imagine software. These techniques will continue to impact our field in many ways as new applications are found.

In addition to the land use/cover changes in the UBR, damming has isolated all 5 tributaries from one another. Changes to the Barren River system can be observed by looking at pre-impoundment and post-impoundment historic aerial imagery (Figure 6). It is important to delineate the lasting effects anthropogenic impacts can have on a freshwater system. The dam construction in the UBR has lead to potential increased problems for the blackfin sucker. In addition to the dam, increased agricultural land use is growing at a rapid rate. Agriculture further contributes to sedimentation, observed in the field, and other habitat altering effects such as increased degradation and temperature. In this study, agriculture was not found to be a driving factor in blackfin sucker CPUE, however, it could become more of a problem over time as more changes occur within the watersheds and effects of the dam become more prominent. We can continue to monitor the land use/cover changes and focus conservation planning and efforts in multiple directions.

An idea for future efforts may be to perform research similar to that of Fluker et al. (2014). Fluker et al. (2014) explained that when landscape is altered and stream connectivity becomes fragmented, genetic characteristics and gene flow can be negatively impacted and can even lead to the extinction of local populations. For the endemic blackfin sucker this could lead to complete extinction since the UBR is host to the only known population. During his field work, Stringfield (2014) collected blackfin sucker fin clips to be used in future genetic analyses. Decreased mobility alone is cause to focus further conservation efforts on this species and its habitat.

The damming of the Barren River has presented the UBR with its most drastic change. Blackfin sucker habitat has been altered, fish migration routes hindered, and genetic dispersal between drainages reduced (Stillings 2010). Since the blackfin sucker is a species of special conservation concern and due to its endemic status it is important for a conservation plan to be developed in order for this species to survive. The blackfin sucker populations in the UBR are the only known blackfin sucker gene pools, and therefore are a special conservation case (Stillings 2010). Further field work should be done in order to potentially provide more information on the size and health of blackfin sucker populations in the UBR and further monitoring of land use/cover could produce different results over time.

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APPENDIX A:

TABLES

Table 1. Sites used in Stringfield project (2011-2012) and land use and cover extractions (2015).

Site	Date	State	Watershed	Longitude	Latitude
1	10/25/2011	KY	Skaggs	-85.86772	36.91849
2	10/25/2011	KY	Peter	-85.79919	36.77454
3	11/1/2011	KY	Peter	-85.96371	36.84828
4	11/8/2011	KY	Long	-86.11202	36.65903
5	3/20/2012	KY	Skaggs	-85.77105	36.89582
6	3/20/2012	KY	Skaggs	-85.80309	36.92746
7	4/3/2012	KY	Peter	-85.95515	36.84978
8	4/3/2012	KY	Peter	-85.9644	36.83337
9	4/10/2012	KY	Skaggs	-85.80062	36.85298
10	4/10/2012	KY	Peter	-85.91249	36.80327
11	4/17/2012	KY	Long	-86.10652	36.64832
12	4/17/2012	KY	Long	-86.10719	36.70354
13	4/17/2012	KY	Barren River	-86.00544	36.62972
14	4/24/2012	KY	Barren River	-86.02689	36.65726
15	4/24/2012	KY	Barren River	-85.9559	36.69439
16	4/24/2012	TN	Barren River	-86.01171	36.61952
17	5/11/2012	TN	Barren River	-85.93372	36.51406
18	5/11/2012	TN	Barren River	-85.7794	36.55991
19	5/17/2012	TN	Barren River	-85.97822	36.5931
20	5/17/2012	TN	Barren River	-85.92301	36.5983
21	5/17/2012	TN	Barren River	-85.882	36.59101
22	6/7/2012	KY	Barren River	-85.73988	36.66641
23	6/7/2012	KY	Barren River	-85.78442	36.67397
24	6/21/2012	TN	Barren River	-85.73127	36.6094
25	6/21/2012	TN	Barren River	-85.71406	36.60934
26	8/23/2012	TN	Barren River	-85.87322	36.55429
27	8/23/2012	TN	Barren River	-85.85432	36.58025
28	8/30/2012	KY	Beaver	-85.82271	36.99842
29	8/30/2012	KY	Beaver	-85.80919	37.00904
30	8/30/2012	KY	Skaggs	-85.90047	36.94277
31	9/13/2012	TN	Long	-86.14658	36.59448
32	9/13/2012	TN	Long	-86.11602	36.58701
33	10/4/2012	TN	Barren River	-85.9884	36.5299
34	10/4/2012	TN	Barren River	-86.02171	36.59214
35	10/10/2012	KY	Skaggs	-86.73489	36.80706
36	10/10/2012	KY	Barren River	-85.91197	36.71219

Table 1. continued.

Site	Date	State	Watershed	Longitude	Latitude
37	10/25/2012	KY	Long	-86.11237	36.7773
38	10/25/2012	KY	Long	-86.07822	36.7362
39	11/1/2012	TN	Barren River	-85.83855	36.5754
40	11/15/2012	KY	Barren River	-85.84696	36.665
41	11/15/2012	KY	Barren River	-85.82536	36.6874

Source: Stringfield, Cory D. 2013. Population Distribution and Abundance of the Blackfin Sucker (*Thoburnia atripinnis*) in the Upper Barren River System, Kentucky and Tennessee. Master's Thesis, Eastern Kentucky University, Richmond.

Table 2. Physicochemical data and other data from Stringfield study, 2011-2012.

Site	State	Temp. ©	D.O. (mg/L)	pH (S.U.)	Conductivity (µS)	CPUE Blackfins/min	Abundance
1	KY	13.8	7.76	8.35	351	0.000	0
2	KY	13.3	5.45	8.6	297.8	0.000	0
3	KY	15.4	3.07	9.1	263.5	0.633	18
4	KY	14.2	5.58	8.28	190.2	0.048	1
5	KY	17.4	9.25	8.93	259.7	0.000	0
6	KY	19.4	7.7	8.78	261.3	0.000	0
7	KY	18.9	9.72	8.64	246.7	0.566	19
8	KY	21.4	5.09	8.57	284.1	0.000	0
9	KY	14.7	12.44	8.81	412.6	0.040	1
10	KY	15.7	7.17	8.87	265.4	0.000	0
11	KY	16.5	6.62	8.49	179.5	0.063	2
12	KY	15.3	6.48	8.51	228.1	0.000	0
13	KY	15.7	6.32	8.46	183.7	0.096	3
14	KY	14.3	5.84	8.29	184.7	0.252	10
15	KY	13.9	6.91	8.73	274.1	0.030	1
16	TN	13.9	6.24	8.7	168.2	0.025	1
17	TN	17.4	5.92	8.36	203.1	0.085	3
18	TN	19.9	4.49	8.75	200.8	0.849	27
19	TN	19	4.34	8.55	187.4	0.679	24
20	TN	19.8	3.93	8.3	194.1	0.103	2
21	TN	23.1	3.89	8.34	185.1	0.480	16
22	KY	19.8	10.99	8.68	405.6	0.659	20
23	KY	21.6	7.38	8.58	283.3	0.081	2
24	TN	24.8	8.44	8.75	337.7	0.284	10
25	TN	22.7	5.93	8.49	335	0.145	4
26	TN	22.8	6.9	7.98	191.3	0.203	7
27	TN	21.1	8.89	8.37	218.7	1.080	36
28	KY	21.4	6.08	8.11	432.3	0.000	0
29	KY	21.4	5.98	8.39	484.3	0.000	0
30	KY	24.4	5.86	8.64	550	0.688	22
31	TN	19.7	7.39	8.53	270.6	0.772	24
32	TN	21.4	7.89	8.51	215.1	0.000	0
33	TN	17.8	7.89	8.33	160.5	0.686	25
34	TN	17.8	8.01	8.13	200.4	0.235	8
35	KY	12.6	12.41	8.57	348.9	0.000	0
36	KY	12.6	9.62	8.59	313.6	0.479	16
37	KY	13.1	10.22	8.3	297.7	0.095	3

Table 2. continued.

Site	State	Temp. ©	D.O. (mg/L)	pH (S.U.)	Conductivity (µS)	CPUE Blackfins/min	Abundance
38	KY	17.4	7.32	8.12	281.3	0.345	9
39	TN	9.5	13.24	8.52	159.4	0.582	14
40	KY	6.3	6.69	7.85	198.7	0	0
41	KY	10.4	9.92	8.19	289	0	0

Source: Stringfield, Cory D. 2013. Population Distribution and Abundance of the Blackfin Sucker (*Thoburnia atripinnis*) in the Upper Barren River System, Kentucky and Tennessee. Master's Thesis, Eastern Kentucky University, Richmond.

Table 3. An error matrix for the supervised classification generated from the classification data and ground data for the September 5, 2015 satellite image of study area.

	Reference Data						
Classified Data	Water	Developed	Forest	Hay Pasture	Agriculture	Total	User's Accuracy
Water	47	0	1	0	2	50	94.00%
Developed	2	32	4	1	11	50	64.00%
Forest	0	1	47	1	1	50	94.00%
Hay Pasture	0	2	0	45	3	50	90.00%
Agriculture	1	0	0	8	41	50	82.00%
Column Total	50	35	52	55	58	250	
Producer's Accuracy	94.00%	91.43%	90.38%	81.82%	70.69%		

Overall accuracy = 84.80%. Overall kappa = 0.8100

Table 4. An error matrix for the unsupervised classification generated from the classification data and ground data for the September 5, 2015 satellite image of study area.

Classified Data	Reference Data						
	Water	Developed	Forest	Hay Pasture	Agriculture	Total	User's Accuracy
Water	48	4	0	0	2	54	88.89%
Developed	0	11	0	6	26	43	25.58%
Forest	2	11	51	9	2	75	68.00%
Hay Pasture	0	9	1	25	24	59	42.37%
Agriculture	0	0	1	15	3	19	15.79%
Column Total	50	35	53	55	57	250	
Producer's Accuracy	96.00%	31.43%	96.23%	45.45%	5.26%		

Overall accuracy = 55.20%. Overall kappa = 0.4399

Table 5. Land use and land cover class proportions extracted in ArcGIS with 100m buffers.

Site	%Forest	%Water	%Developed	%Hay Pasture	%Cultivated Crops	%Other
1	1.85	0.00	44.44	24.07	29.63	0.00
2	0.00	0.00	29.63	70.37	0.00	0.00
3	85.19	0.00	0.00	12.96	0.00	1.85
4	29.63	0.00	7.41	20.37	42.59	0.00
5	29.63	0.00	7.41	20.37	42.59	0.00
6	53.70	0.00	0.00	46.30	0.00	0.00
7	55.56	0.00	5.56	38.89	0.00	0.00
8	22.22	0.00	24.07	53.70	0.00	0.00
9	24.07	0.00	7.41	40.74	27.78	0.00
10	25.93	0.00	18.52	55.56	0.00	0.00
11	68.52	0.00	0.00	31.48	0.00	0.00
12	94.44	0.00	5.56	0.00	0.00	0.00
13	20.37	0.00	35.19	44.44	0.00	0.00
14	81.48	0.00	0.00	0.00	0.00	18.52
15	46.30	0.00	25.93	27.78	0.00	0.00
16	37.04	0.00	0.00	0.00	0.00	62.96
17	66.67	0.00	20.37	0.00	0.00	12.96
18	28.30	0.00	28.30	43.40	0.00	0.00
19	64.81	0.00	20.37	14.81	0.00	0.00
20	53.70	0.00	27.78	5.56	12.96	0.00
21	25.93	0.00	22.22	31.48	0.00	20.37
22	40.74	0.00	24.07	33.33	1.85	0.00
23	64.81	0.00	1.85	29.63	0.00	3.70
24	62.96	0.00	25.93	11.11	0.00	0.00
25	18.52	0.00	20.37	61.11	0.00	0.00
26	75.93	0.00	0.00	24.07	0.00	0.00
27	40.74	0.00	24.07	25.93	9.26	0.00
28	18.52	0.00	22.22	59.26	0.00	0.00
29	44.44	0.00	7.41	48.15	0.00	0.00
30	37.04	0.00	22.22	40.74	0.00	0.00
31	68.52	0.00	1.85	0.00	0.00	29.63
32	72.22	0.00	3.70	0.00	5.56	18.52
33	79.63	0.00	0.00	7.41	12.96	0.00
34	20.37	0.00	18.52	61.11	0.00	0.00
35	16.67	0.00	31.48	51.85	0.00	0.00

Table 5. continued.

Site	%Forest	%Water	%Developed	%Hay Pasture	%Cultivated Crops	%Other
36	55.56	0.00	0.00	12.96	31.48	0.00
37	98.15	0.00	0.00	1.85	0.00	0.00
38	85.19	0.00	0.00	0.00	0.00	14.81
39	74.07	0.00	11.11	1.85	0.00	12.96
40	35.19	0.00	0.00	1.85	46.3	16.67
41	94.44	0.00	0.00	5.56	0.00	0.00

Table 6. Land use and land cover class proportions extracted in ArcGIS with 390m buffers.

Site	%Forest	%Water	%Developed	%Hay Pasture	%Cultivated Crops	%Other
1	3.25	0.00	11.19	54.87	30.69	0.00
2	10.37	0.00	16.89	72.74	0.00	0.00
3	47.71	0.00	1.20	39.52	0.00	11.57
4	36.65	0.00	5.10	50.24	8.01	0.00
5	48.38	0.00	7.70	23.35	20.34	0.24
6	17.57	0.00	11.55	54.15	16.73	0.00
7	31.81	0.00	6.51	61.69	0.00	0.00
8	36.51	0.00	9.28	54.22	0.00	0.00
9	28.55	0.00	7.95	43.86	19.64	0.00
10	27.95	0.00	8.31	63.73	0.00	0.00
11	52.07	0.00	6.81	38.20	2.92	0.00
12	82.83	0.00	1.93	8.71	0.00	6.53
13	51.82	0.00	11.31	33.94	2.92	0.00
14	72.66	0.00	0.36	10.33	0.00	16.65
15	58.89	0.00	4.84	34.70	0.00	1.57
16	64.84	0.00	8.27	1.22	0.00	25.67
17	62.00	0.00	8.53	0.00	0.00	29.48
18	41.53	0.00	8.65	49.21	0.00	0.61
19	66.55	0.00	7.30	24.21	0.61	1.34
20	69.71	0.00	3.77	1.70	18.13	6.69
21	41.24	0.00	4.62	30.54	0.00	23.60
22	28.85	0.00	10.91	48.61	11.64	0.00
23	44.43	0.00	2.18	46.37	0.00	7.02
24	44.65	0.00	5.96	30.78	16.79	1.82
25	25.30	0.00	11.19	62.17	0.00	1.34
26	67.36	0.00	4.51	28.14	0.00	0.00
27	59.44	0.00	8.89	23.26	8.40	0.00
28	22.81	0.00	21.61	55.58	0.00	0.00
29	25.57	0.00	7.80	66.63	0.00	0.00
30	32.93	0.00	6.61	45.55	13.22	1.68
31	76.52	0.00	4.26	0.12	0.00	19.10
32	70.28	0.00	3.53	0.00	4.38	21.80
33	66.87	0.00	3.41	12.42	14.62	2.68
34	66.30	0.00	6.08	22.87	0.36	4.38
35	30.00	0.00	8.92	61.08	0.00	0.00

Table 6. continued.

Site	%Forest	%Water	%Developed	%Hay Pasture	%Cultivated Crops	%Other
36	41.23	0.00	4.84	23.70	30.23	0.00
37	83.72	0.00	1.09	15.20	0.00	0.00
38	71.95	0.00	3.14	16.93	0.97	7.01
39	68.21	0.00	1.83	29.11	0.00	0.85
40	42.84	0.00	3.40	9.83	16.87	27.06
41	61.67	0.00	5.56	32.41	0.36	0.00

Table 7. Full watershed land use and land cover proportions extracted in ArcGIS.

	%Forest	%Water	%Developed	%Pasture	%Cultivated Crops	%Other
Beaver	26.5	0.91	12.1	55.8	3.8	0.80
Skaggs	35.5	1.77	5.8	48.6	6.5	1.78
Peter	35.7	1.08	5.4	50.2	5.8	1.77
Barren	48.5	0.12	5.7	36.1	5.7	3.87
Long	54.0	0.02	5.7	28.9	7.6	3.90

Table 8. Principal component analysis (PCA) at 100m of 11 land use and physicochemical variables. The bold values indicate the greatest loading for each principal component.

PCA loadings and variability by component	PC1	PC2	PC3
Forest	**0.4053**	-0.1260	-0.3604
Developed	**-0.4206**	-0.0867	0.1636
Hay Pasture	**-0.5001**	-0.0118	0.0548
Agriculture	0.0531	**0.5459**	0.3988
Other	0.3699	-0.1619	0.0932
Temperature	-0.2300	**-0.5336**	-0.0628
Dissolved Oxygen	0.0176	**0.5347**	**-0.4162**
pH	-0.2200	-0.0597	-0.1602
Conductivity	-0.3462	0.1777	-0.2594
Average Reach Depth	0.1444	-0.0788	**0.6025**
Elevation	0.1636	-0.2005	-0.1988
Percentage total variance explained	28.115	14.740	13.765

Table 9. Principal component analysis (PCA) at 390m of 11 land use and physicochemical variables. The bold values indicate the greatest loading for each principal component.

PCA loadings and variability by component	PC1	PC2	PC3
Forest	**0.4538**	0.1117	-0.1096
Developed	-0.3759	-0.1402	-0.1780
Hay Pasture	**-0.4582**	-0.0740	-0.0838
Agriculture	-0.1176	0.2548	**0.5314**
Other	**0.4011**	-0.1996	0.0303
Temperature	-0.1150	**-0.5317**	-0.1793
Dissolved Oxygen	-0.115	**0.6858**	-0.0479
pH	-0.2060	-0.1651	0.0969
Conductivity	-0.3843	0.0269	-0.0083
Average Reach Depth	0.1462	-0.2666	**0.5819**
Elevation	0.1823	0.0739	**-0.5324**
Percentage total variance explained	32.146	14.054	12.731

Table 10. Correlation coefficients (with associated p-values) between blackfin sucker CPUE and the first (PC1) second (PC2) and third principal component (PC3). *p* values represent a two-tailed probability.

	Blackfin sucker catch per unit effort (CPUE)			
	100m		390m	
	R	*P*	R	*P*
PC1	0.07	0.66	0.15	0.35
PC2	-0.27	0.09	-0.10	0.53
PC3	-0.13	0.42	-0.13	0.42

APPENDIX B:

FIGURES

Figure 1. Photograph of the endemic blackfin sucker found exclusively in the Upper Barren River KY (picture taken by Matt Thomas, KDFWR).

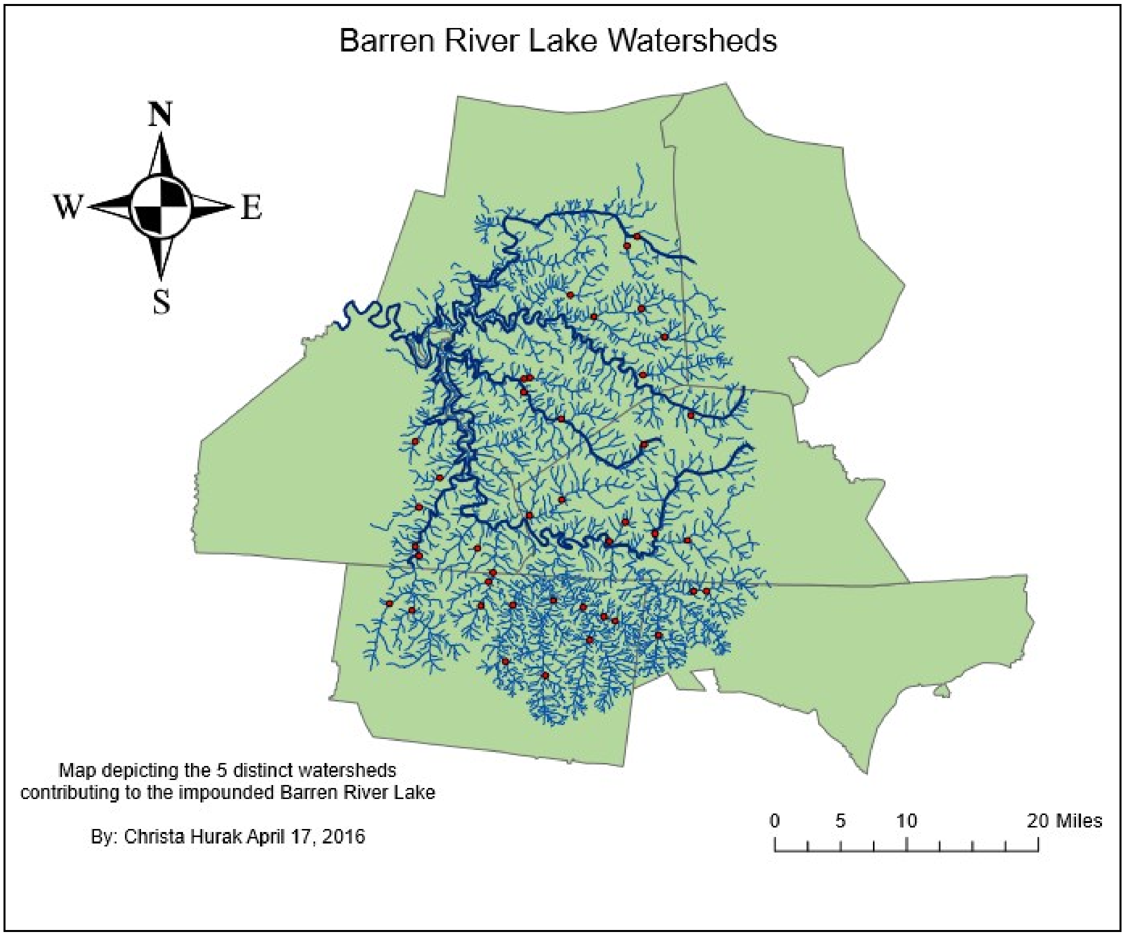

Figure 2. Map of 41 sampling sites utilized for fish data collection in 2013 Stringfield study.

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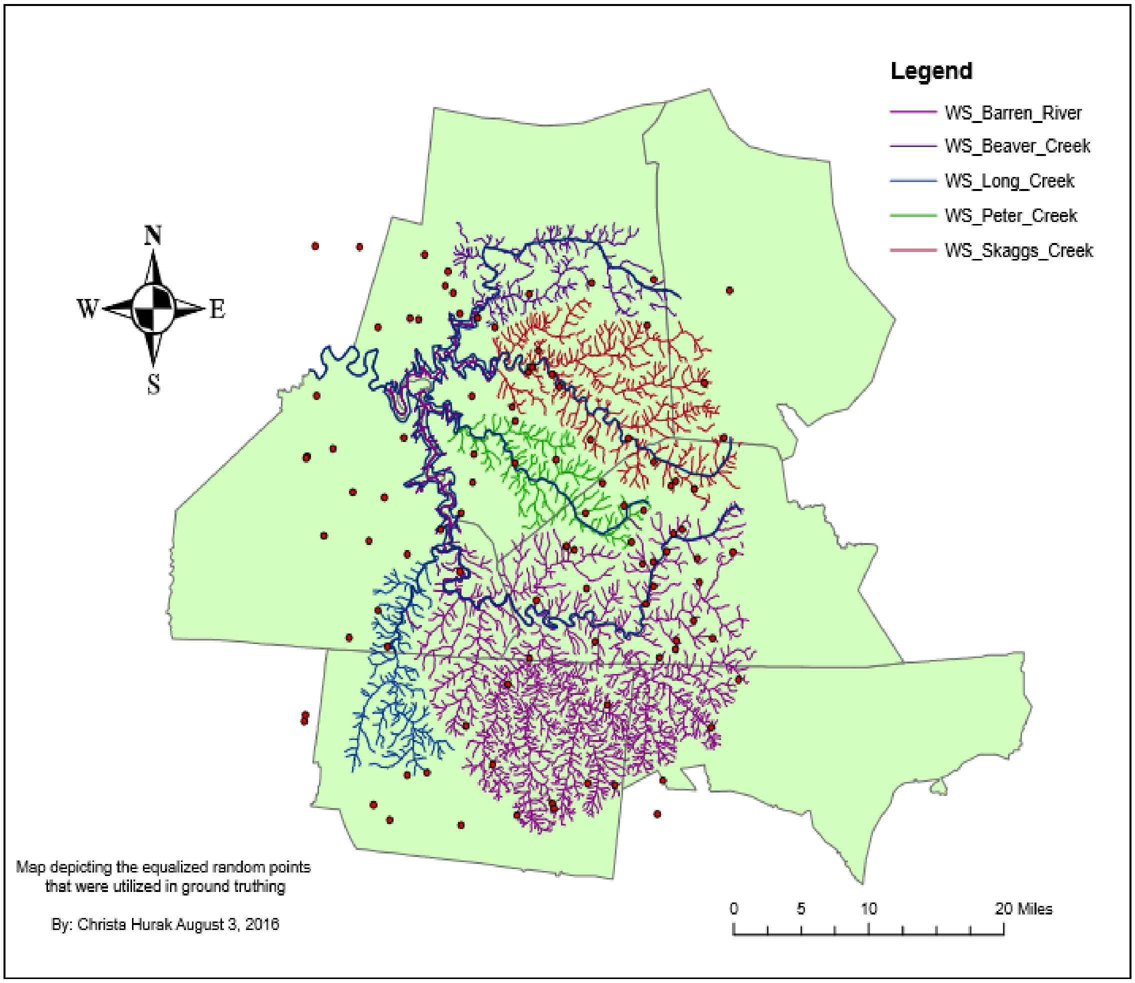

Figure 3. Map of equalized random GPS points used in ground truthing for supervised classification

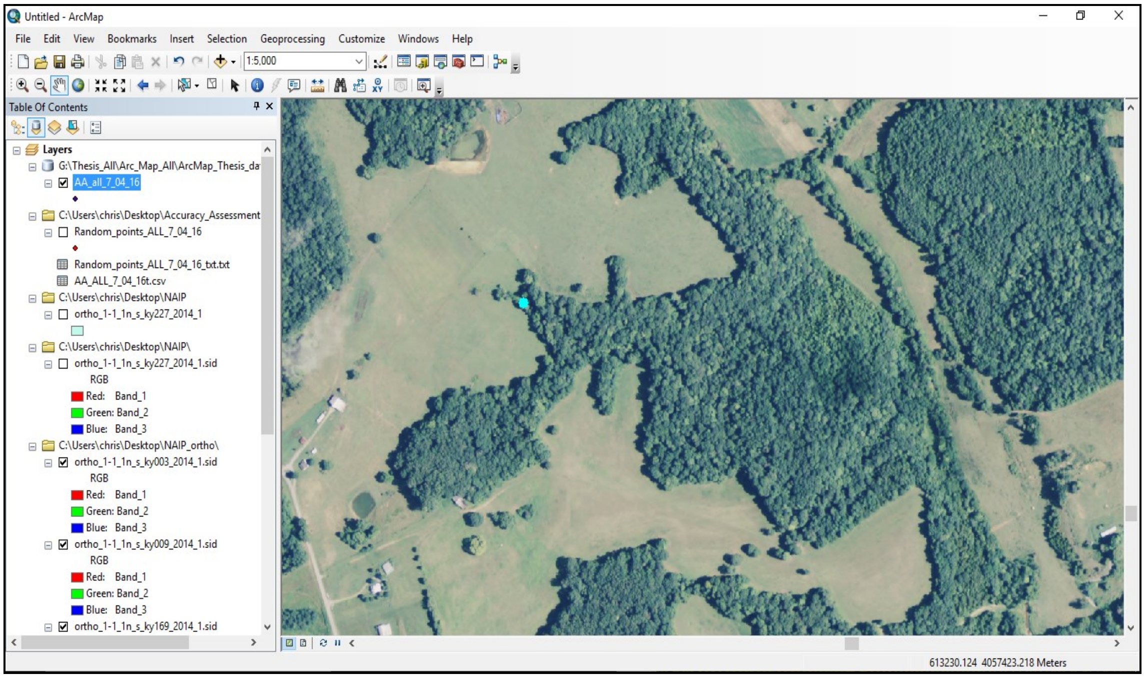

Figure 4. Example NAIP satellite image (2014) used for land use/cover verifications.

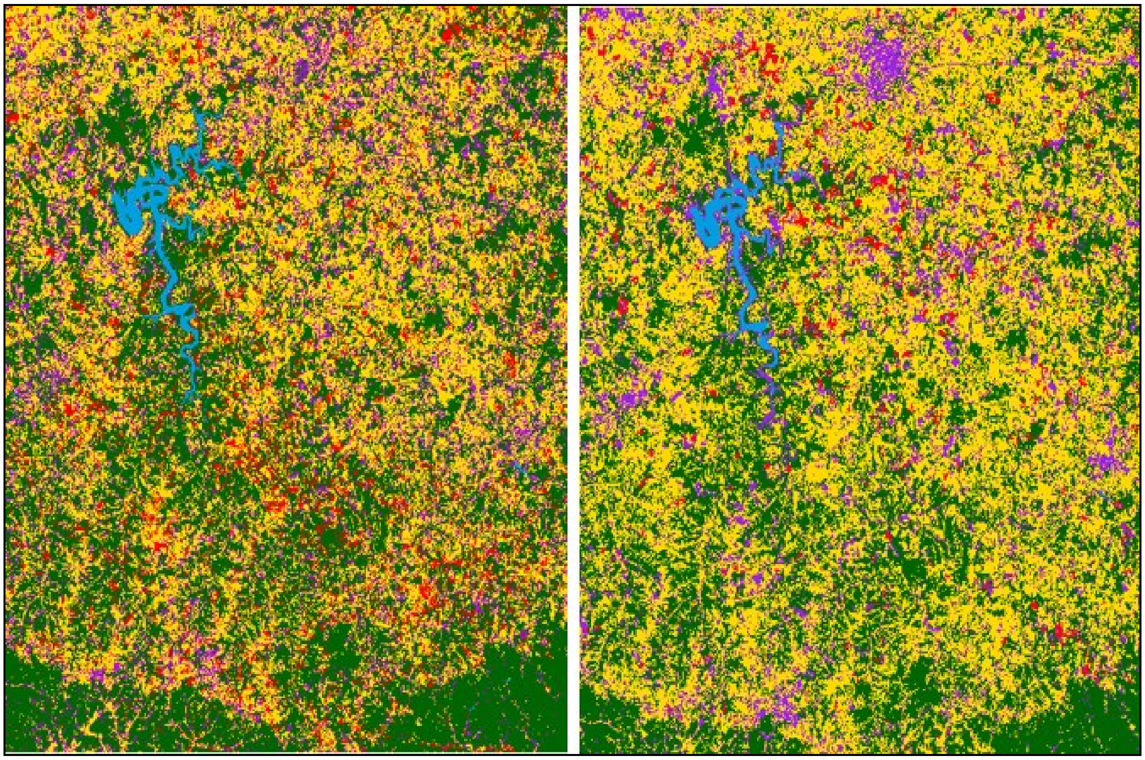

Figure 5. Unsupervised and supervised classification of satellite imagery acquired (September 5, 2015) of Barren River study area.

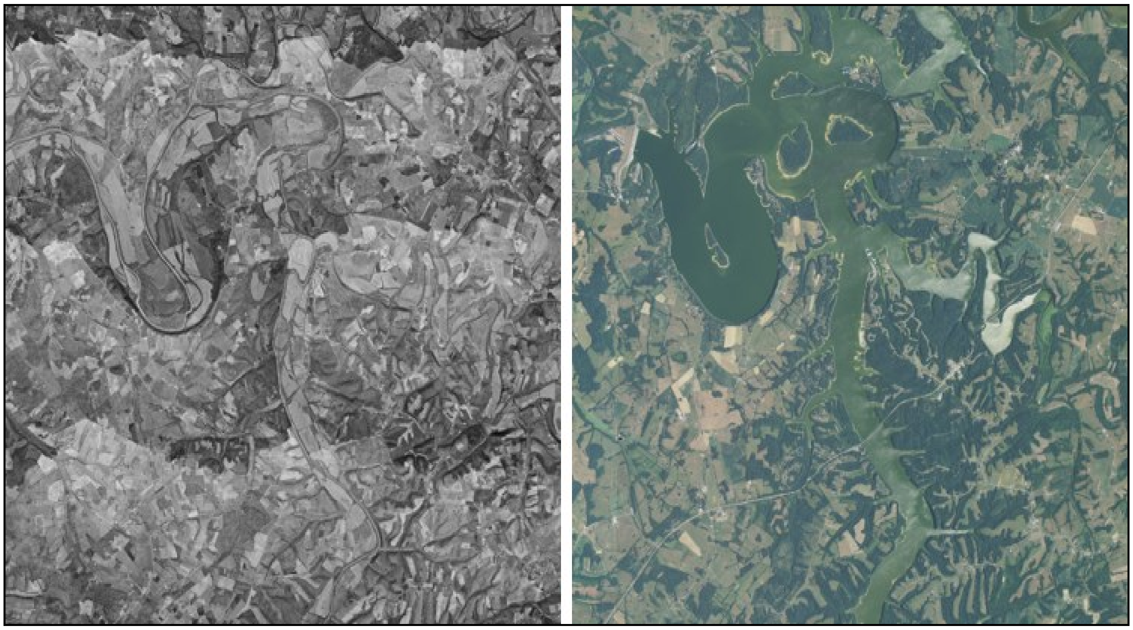

Figure 6. Historic image (1953) versus current image (2012) of Barren River reservoir.